Selective resonance reading from double-layer recording magnetization using a spin-torque oscillator

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Three dimensional (or multilayer) magnetic recording which utilizes ferromagnetic resonance (FMR) has been proposed as a method for increasing the recording density [1,2,3]. The recording layers have different FMR frequencies, which enables selective writing or reading of a layer by applying microwave field with a respective frequency. The microwave field is generated by a spin-torque oscillator (STO). This write operation is a multilayer version of microwave-assisted magnetization switching (MAS) [4,5]. The MAS has been investigated because its application for next-generation assisted recording has been expected.

The read operation utilizes changes in the STO oscillation which occur when the STO induces FMR excitation in a recording layer. This method is thus called resonance reading. The layer-selective FMR excitation has been shown in magnetic multilayer films by using a signal generator [6,7]. The resonance reading using the STO has been demonstrated on a sample where the STO and a recording magnetization are fabricated close [8]. By using micromagnetic simulation, transient magnetization dynamics during the resonance reading (from a single recording layer) has been studied and a response within a time scale of 1 ns has been shown[9]. Based on the obtained waveform of the STO, detection methods for the resonance reading have been proposed[10,11].

Recently, we have demonstrated the selective resonance reading from double-layer recording magnetizations using the STO in micromagnetic simulation[12]. Figure 1 shows schematic of the STO and the recording magnetizations with double recording layers. The STO consists of a perpendicular free layer and in-plane fixed layer[13]. Each recording layer consists of a soft layer and a hard layer, which have lower and higher perpendicular anisotropies, respectively. The soft layers are used in the read operation, while the hard layers keep written data. The magnetizations of the soft and hard layers are directed in opposite perpendicular directions by interlayer antiferromagnetic coupling. The magnetization states of the recording layers are called up or down states depending on the magnetization direction of the soft layers. For the recording magnetizations (RMs) an external perpendicular field H_z^{RM} is applied, which makes the FMR frequencies different for the up and down states. Parameters are chosen so that following two conditions are met. The first condition is that the response of the STO for the FMR excitation in the soft layer 2 is large enough. The second condition is that the FMR frequency of the soft layer in one recording layer is unaffected by the magnetization state of the other recording layer.

Figure 2 shows the waveforms of the magnetizations obtained in the micromagnetic simulation where the STO is moved over an array of 6 recording magnetizations with staggered magnetization configuration. The time evolution of the y-components of the magnetizations are shown. The y-component of the STO corresponds to a signal by the magnetoresistive effect since the magnetization of the fixed layer is in the y-direction. The STO oscillation frequency is set near to the FMR frequency of the soft layer 2 in the down state. In Fig. 2(a), when the STO approaches the soft layer 2 in down state, the magnetization oscillation is excited. At the same time, the STO oscillation amplitude decreases owing to increased effective damping. When the STO is near the soft layer 2 in the up state, the amplitude recovers. From this difference in the oscillation of the STO, the magnetization states in the recording layers 2 can be detected. In Fig. 2(b), the magnetization directions of the recording layer 1 are opposite to those in Fig. 2(a). It is found that the waveforms are almost the same. This result means that the magnetization directions of the recording layers 2 can be detected independent of those of the recording layer 1. The independent detection of the magnetization direction in a recording layer enables the layer-selective reading as if there are two single-layered discs on one medium. In the presentation, future problems on the layer-selective resonance reading will be discussed, such as effects of stray fields between the recording magnetizations.

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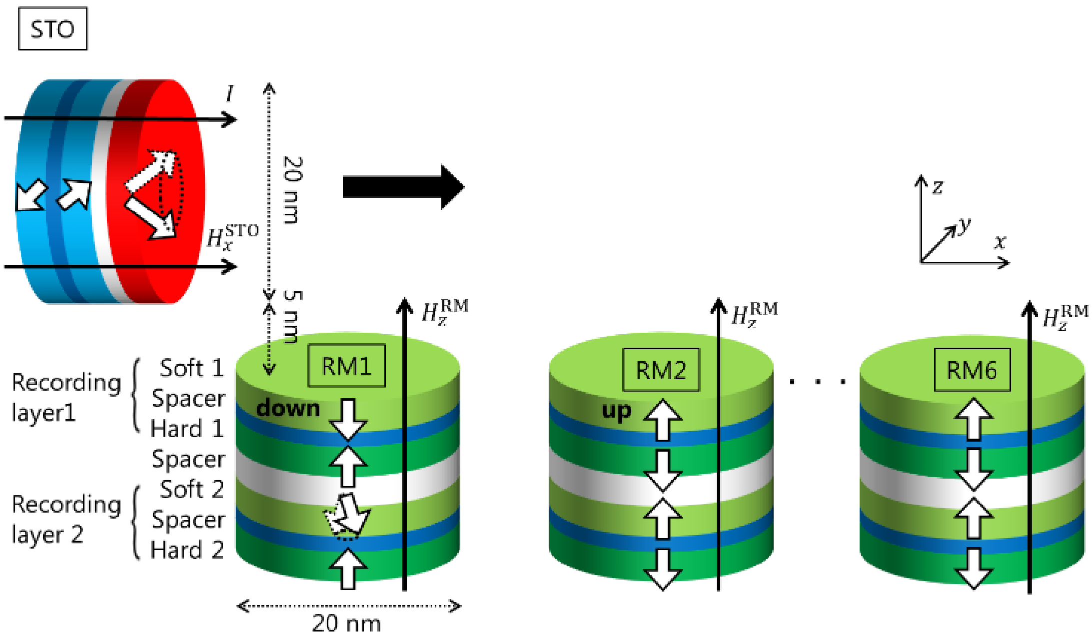

Fig. 1. Schematic of a spin-torque oscillator (STO) and recording magnetizations with two recording layers (RMs).

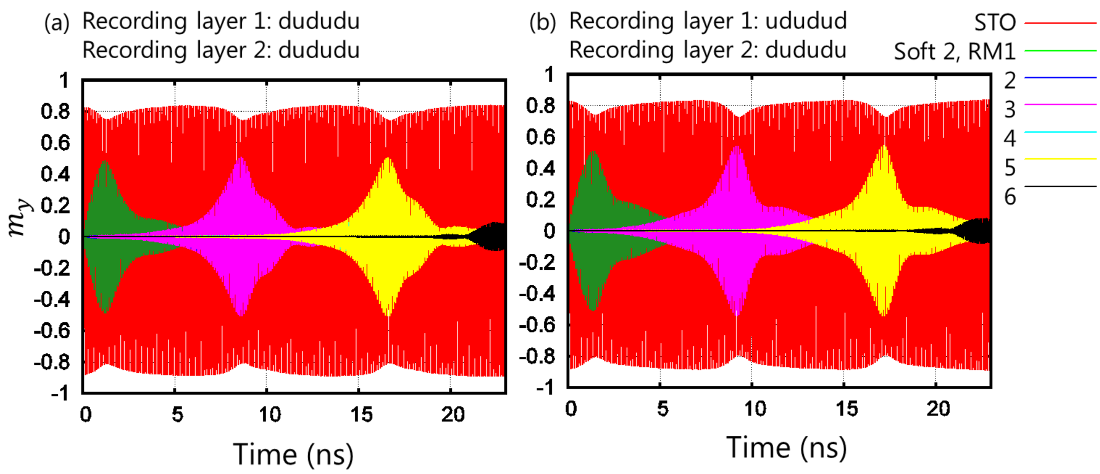

Fig. 2. Time evolution of y-components of magnetizations. In (b), magnetization directions of recording layer 1 are opposite to those in (a). Letters “u” and “d” denote up and down states of the recording layers.